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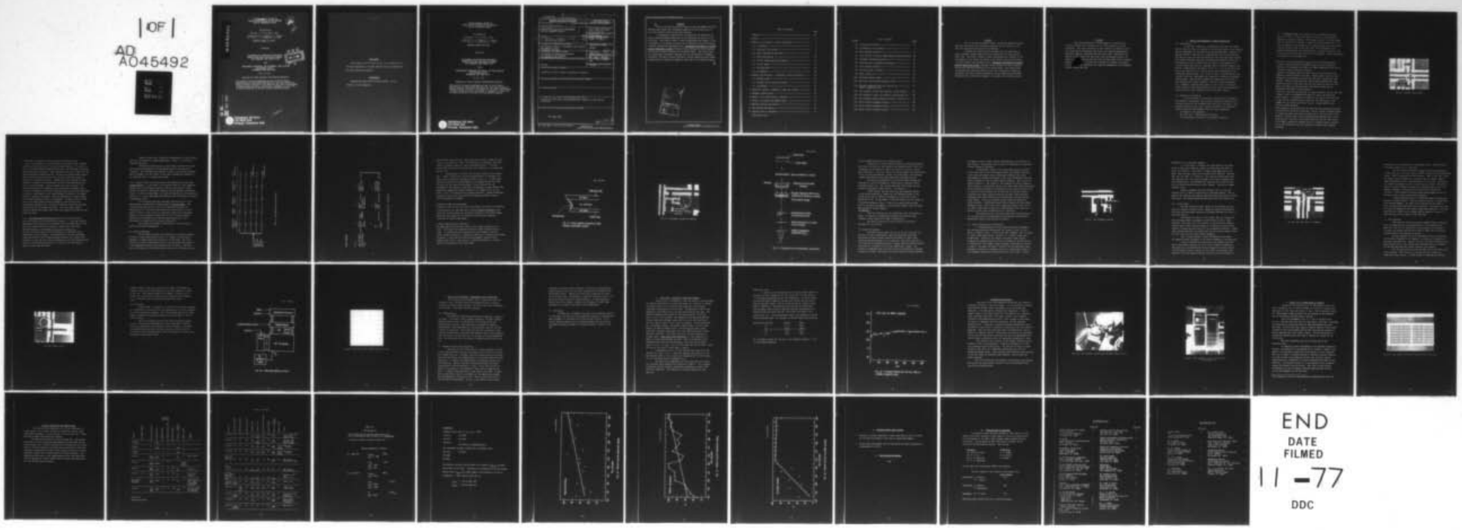

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FOURTH QUARTERLY REPORT ON MANUFACTURING METHODS AND ENGINEERING FOR TFT ADDRESSED DISPLAY

②

for period of

February 7, 1977 to May 7, 1977

Prepared by D. H. Davies, W. L. Rogers,
F. C. Luo, S. D. Burkholder, M. Green

CONTRACT DAAB07-76-C-0027

placed by

PROCUREMENT AND PRODUCTION DIRECTORATE
UNITED STATES ARMY ELECTRONICS COMMAND
FORT MONMOUTH, NEW JERSEY 07703

with

WESTINGHOUSE INDUSTRIAL AND GOVERNMENT TUBE DIVISION
WESTINGHOUSE CIRCLE
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July 10, 1977

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ABSTRACT

This is the Fourth Quarterly Report on Contract DAAB07-76-C-0027; manufacturing methods and technology evaluation for the fabrication of thin film transistor based solid state displays.

A significant reason has been uncovered for the difference in quality between displays fabricated on the laboratory X-Y units and the pilot line. This factor relates to mask contamination and transfer of the contaminants to the glass; the result is an increase in electrical shorts. A partial solution was implemented and a consequent improvement in display quality immediately evident although further advances are still required. Several more rigorous solutions are now being tested. The overall pilot line operational reliability improved with the introduction of modified procedures; the major residual problems is circuit opens and microcracked insulators both of which are thought at this time to be relatively minor.

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ABSTRACT

This is the Fourth Quarterly Report on Contract DAAB07-76-C-0027; manufacturing methods and technology evaluation for the fabrication of thin film transistor based solid state displays.

A significant reason has been uncovered for the difference in quality between displays fabricated on the laboratory X-Y units and the pilot line. This factor relates to mask contamination and transfer of the contaminants to the glass; the result is an increase in electrical shorts. A partial solution was implemented and a consequent improvement in display quality immediately evident although further advances are still required. Several more rigorous solutions are now being tested. The overall pilot line operational reliability improved with the introduction of modified procedures; the major residual problems is circuit opens and microcracked insulators both of which are thought at this time to be relatively minor.

1. PURPOSE

The overall objective of this program is to develop mass production methods and techniques for thin film transistor display technology. This novel technology is most amenable to computer control and the methods in development are based on an existing,Westinghouse developed, computer controlled thin film pilot line. Versions of the display in development have been made, with considerable success, in laboratory style equipment and this work continues under direct corporate support. [illegible] program includes the development of methods, procedures and op[illegible]cipes followed by the rigorous examination of the displays for performance and life.

2. RESULTS AND DISCUSSION - CIRCUIT FABRICATION

2.1 Introduction

It has been evident for a considerable time that the changes made in the pilot line, as detailed in the previous reports, have improved the key ingredients of film quality and pattern sharpness. However, the display results to date had not correlated well with our expectations. Put simply we know from previous experience that given good film quality and pattern sharpness, and given acceptable TFT properties (which have been adequate or better almost from the onset of the program), the circuits should have given us reasonable quality displays. However they did not; consequently we decided to add Dr. F. C. Luo to the pilot line team to see what small but critical factor we had overlooked in the technology transfer phase. As a result of this a detailed analysis and a series of specific experiments was conducted to isolate key potential problem areas. Each specific problem area identified as a result of that analysis will now be discussed. The major circuit parameters (e.g. alignment, sharpness,film quality, etc.) as well as the post-anneal properties (TFT characteristics, short count) are tabulated and plotted for the recent fabrication runs in Section 7 below.

2.2 Dielectric Film Quality

The main thrust of the effort to date has been to improve the insulator film quality; the intrinsic dielectric strength is not the prime concern we are confident that this is not the issue -- the problem is defects in the film. Defects observed in the insulator layers during the above analysis fell into three categories.

(a) Cracks in the insulator

(b) Specs etc., deposited with the Al_2O_3.

(c) Contamination external to the material deposited.

2.2.1 Insulator cracks are a minor but not insignificant problem. Fig (1) is typical. They cause shorts if they occur between metal deposits in crossover regions. Their cause is as yet not fully pinned down but appears to be related to substrate moisture absorption. The rapid desorption of water when the hot Al_2O_3 nucleates and forms causes a stress condition that strains the film. Either immediately, or possibly during anneal, the cracking occurs. The major question: why is this virtually never observed in the X-Y displays? Several differences are present in the processes viz;

- The pilot line uses EM-patinal A_2O_3, the X-Y uses Linde sapphire. However, patinal has been successfully used in the X-Y operation
- The pilot line deposits the films at a higher temperature than the X-Y because the throw distance is shorter.

However, calculations show that most heat is in fact derived from condensation which should be the same. Further many of our other lab systems use throw distances shorter than the pilot line without this problem. (Note of course that heat related mask problems which were significant prior to the kovar back ups, are worse for the pilot line since only there are the large area, high density masks used in conjunction with short throw distances.)

- The pilot line uses O_2 back-fill for Al_2O_3 deposition; the X-Y does not. However, this is recommended procedure for Al_2O_3 and should give better quality. Incidentally the reason for its use in the pilot line is that the 10" diffusion pump is such that the residual O_2 in the chamber is much reduced over the X-Y units. Without added O_2 the films are oxide depleted.
- The logistics of the pilot line are such that the overnight pump down is done without liquid N_2 in the trap. The X-Y system is always trapped. Of course the pilot line trap is filled prior to the run itself. This could be a factor since it will certainly effect adsorbed water on the glass surface. We tried a cross-check where we kept the trap filled. It did make a difference although this is a parameter hard to quantify. We are now altering the N_2 fill operation to ensure liqN_2 trapping overnight.

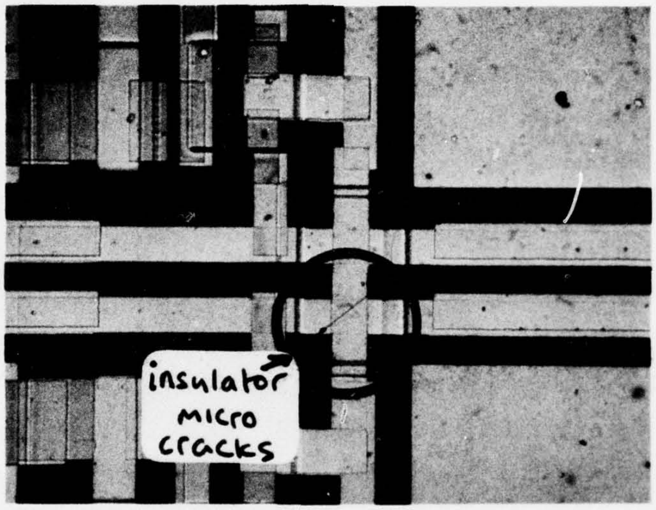

Fig (1) Insulator microcracks

o The glass is "fresher" in the X-Y system vs the pilot line.

This is a consequence of the logistics of the Super Q water cleaning process and the location of the glass cleaning facility. It could be a factor although Corning 7059 glass should have less "blooming" properties than almost any other glass. Water absorption could occur however in the glass holding and transfer process. We have now ordered another Super Q water facility and will build it into the pilot operation located in proximity to the deposition unit. Meanwhile we will organize the glass transfer to expedite its installation on to the substrate holders and into the vacuum chamber. Dry box transfer will also be tried. All these possibilities are dependent on the assumptions regarding cause. To verify or disprove the role of substrate effects we are now conducting a series of experiments in lab vacuum systems in addition to the above tests in the pilot line itself. Also the possibility of insitu baking of the glass substrates will be investigated. The pilot line is fitted with quartz lamp heaters; initial attempts to use them have been unsuccessful because we use low melting adhesives to keep the substrate from falling off the substrate holders. We do have some suitable substrate holders with edge clips rather than adhesive and these are now being evaluated.

2.2.2 Specs deposited with the Al_2O_3 had been the major source of electrical shorts in the circuits until recently. It has been clearly established that these specs were depleted Al_2O_3 (by SEM-X-Ray etc) and they were almost exclusively confined to areas coated with Al_2O_3. The modifications to the shields and gun wells, detailed in the last quarterly report, have now resulted in a consistent major improvement in this property. By preventing well peel and subsequent flake penetration of the e-beam evaporant plasma we have reduced this problem to a very low level. Also contributing is the much improved Sloan controller as described in Section 5. Finally we are screening the Al_2O_3 to remove fine particles.

Overall we have seen a significant improvement in circuit shorts since the introduction of these improvements. Table (1) in Section 7 tabulates the data.

Perhaps more important,the circuits made are definitely stable with operation and shown no new developing shorts as the panels are exercised. This phenomena was prevalent in many of the previous displays and was thought to be the result of very small contaminants embedded in the insulator layer. It appears now solved.

2.2.3. Despite these very clean circuits the displays still show some residual shorts. It only takes a few crossover shorts to ruin legibility however and it was obviously essential that we track down the causes. Tracing the shorts to individual crossovers clearly showed a particulate source. A series of experiments was conducted following the path described in Fig (2). A novel edge lighting scheme was used to evaluate the surface contamination level.

The conclusion from this experiment series was quite clear; some residual contamination is being picked up from the masks. The turbulent pump down was not a factor, the handling inevitable in mounting was not a factor and the evaporation itself was not a factor except in that it acts to bury the previously transferred contaminant. Analysis of this contaminant showed that it also is Al_2O_3 fragments. Repeating this experiment with selected masks showed that it was principally occurring with the insulator masks only.

This problem now becomes a mask problem. The next section details the further developments.

2.3 Mask Contamination

Now the masks themselves are subjected to a rigorous cleaning procedure, shown schematically in Fig (3). Despite this,obviously something is lacking especially relative to the X-Y mask. One clear difference in mask cleaning between the X-Y and dedicated mask approach is the physical scrubbing action possible with the former. The fine pattern tolerances in the dedicated masks require that the masks be thin

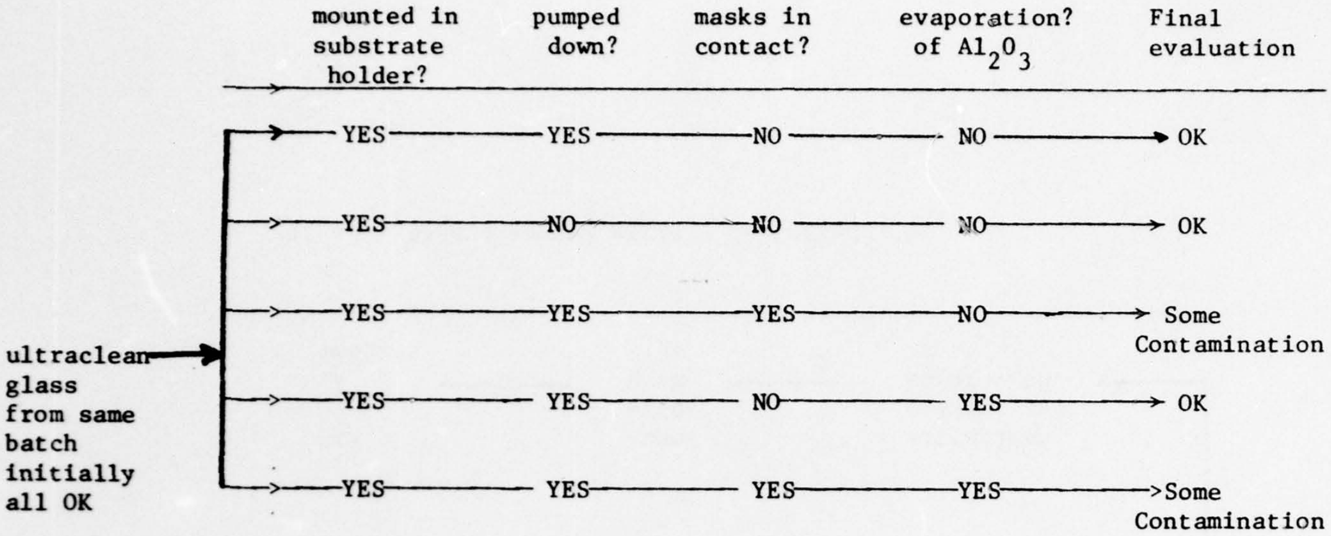

Fig (2) Contamination test sequence

Mask Cleaning

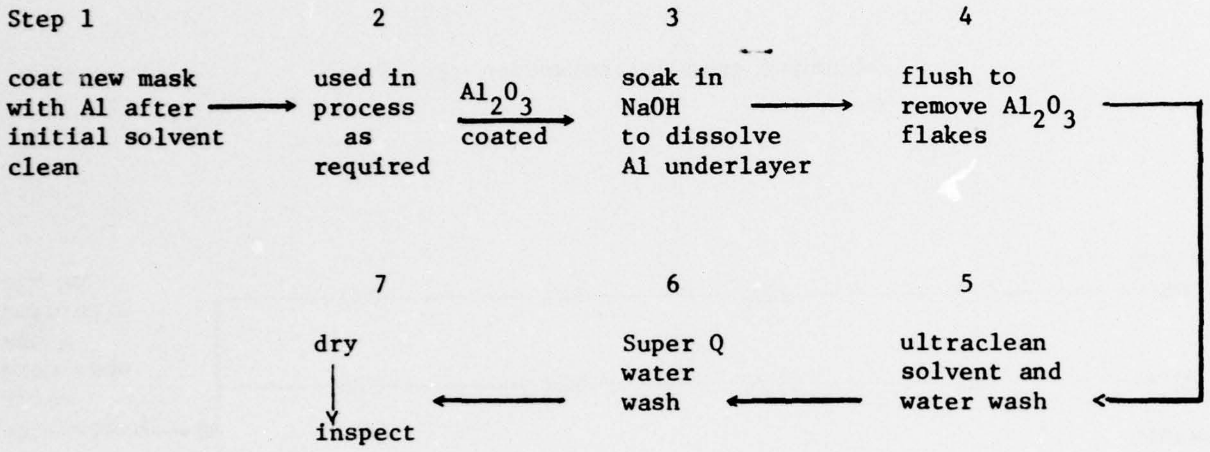

Fig (3) Mask cleaning cycle - dedicated

and therefore quite delicate. Hence they are not given a physical scrub action. This could be a cause; to establish it we examined a so-called clean Al_2O_3 mask in detail at ultra high magnification. It became obvious that the grooves in the multiple film laminates are contaminated, see Fig (4).

Placing glass in contact with the mask transfers this contaminant. Indeed in some cases the entire shaped groove is dislodged, and can be seen on the glass, unbroken as shown in Fig (5). In most cases however the material is quickly mashed to a microparticulate form that is typical of the observed contaminant. Tests indicate that the dislodging of the material occurs when the pneumatic actuator pushes down vigorously (against the release springs) in the magnetic pull up jig action. Fig (6) illustrates the proposed mechanism. Having established a probable cause we now were faced with finding a probable solution. Three approaches were adopted:

- Clean the masks more rigorously.

A physical scrub action, with lint free brushes, was found to be possible providing great care was exercised; likewise heavily attenuated ultrasonics was utilized again with detailed procedures to avoid mask damage. These have been useful but are laborious and relatively dangerous procedures as regards mask damage.

- Obtain masks having no laminates.

The mask supplier fabricated a mask set for us made completely from kovar. This avoids any lamination and should make the mask easier to clean. In addition the kovar mask would be more magnetic, and have better thermal properties. Although the masks were of sufficient tolerance precision, it was found that they were too stiff to operate in the magnetic pull up jig. They did not "conform" sufficiently. An order has been now placed for less stiff masks.

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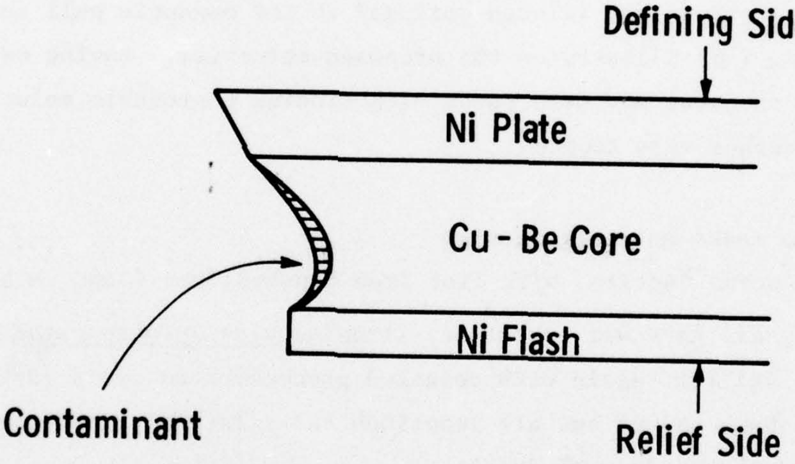

Fig. 4 — Cross section of aperture mask showing lamination groove

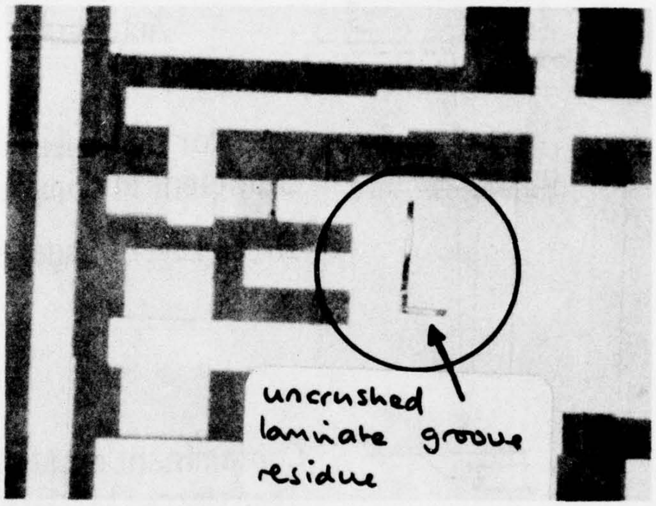

Fig (5) Dislodged contaminant material

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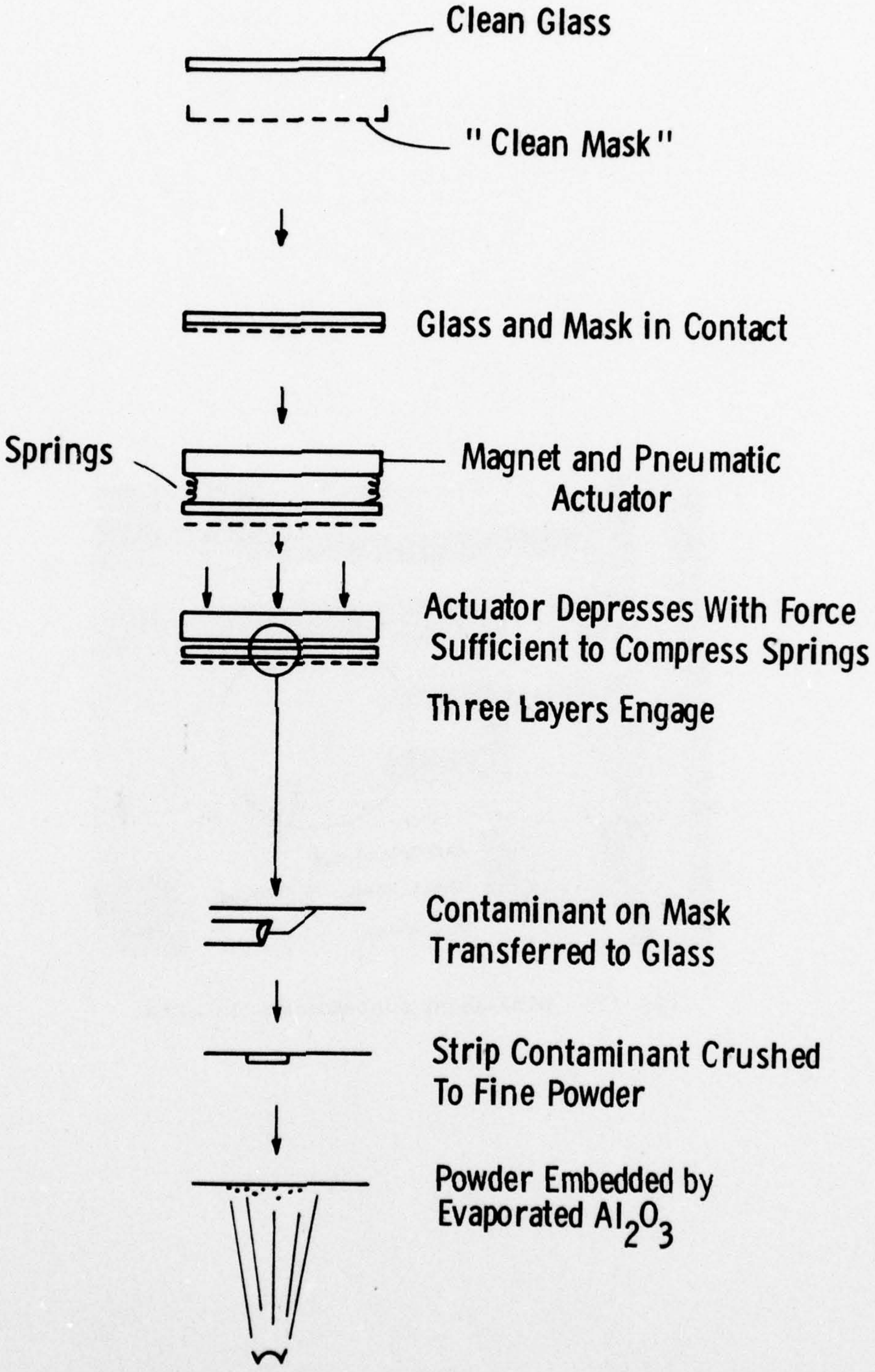

Fig. 6 — Proposed cross contamination mechanism

- Obtain masks having less of a laminate groove.

Examination of typical masks revealed an interesting property. The thinner the mask the less indented the laminate groove. This is a consequence of the degree of copper core etch in the first stage of mask fabrication. We tried a set of the thinner masks; the quality level of the circuits was improved. Repeat of the experiment series showed a marked improvement in the edge illuminated contamination test.

We have now standardized on the thinner masks although the mask maker is still proceeding at a rapid pace to fabricate a more conformable kovar set. The circuits made with this thinner set are definitely improved in short quality. See Section 7.

Lastly another idea was tried that gave improved results. A clean glass substrate is loaded into the substrate holder in the system and is used to "mop-up" the masks as a first step in the deposition cycle. By the amount of material picked up on this glass it is certainly having an effect. This is not a good final solution since it decreases throughput. It will suffice however until the kovar mask process is finally adapted.

<u>To summarize</u>:

Three new features are now incorporated into the process to handle the substrate contamination problem; more effective mask cleaning, thinner masks and a dummy cleaning cycle.

The result is much less circuit shorts, see Section 7, averaging 0-3 per circuit.

2.4 Metal Film Quality

The various metal films (Al, Au, In, Cr, Cu, etc) that are used for bus bars, interconnect, capacitor electrodes and device electrodes must have several required attributes if a short free, stable operational display is to be achieved. The surface texture of the films must be physically smooth in regions where the metals form the electrodes of a crossover that carries significant voltage. The problem is compounded when two metals touch and intermetallic compound formation is likely. The layout and process design already established was based on the X-Y layout already predetermined to be effective in this respect. Nevertheless some variation is impossible to avoid when process transfer is involved.

A significant feature of the metal films recently produced in the pilot line is the clean smooth texture and freedom from specs. A few exceptions however may be significant although their exact relationship to display performance is not fully established; the most obvious exception is the so-called rippled aluminum. Data on this is shown in Section 7. The surface of the aluminum in certain regions is rather rough; it is especially obvious only under "dark field" microscopy and is therefore difficult to photograph. We have seen this before and it relates to film thickness and in particular to multiple layers; we believe that under certain conditions the upper layer nucleates differently and forms a different microcrystalline film that has the rough texture. The use of slightly thinner films has helped this texture problem. Individually probed cells indicate that this slight roughness is not a first order short producing problem since it is a top layer; some further attention is needed however since even top layers can cause punch through defects in insulators.

The overall level of individual metal film microparticles is now very good since the modification of gun hearths to incorporate appropriate liners as was detailed previously.

2.5 Pattern Registration and Sharpness

A creeping problem in recent weeks was pattern alignment; this had been generally satisfactory but started to drift off on a patchy, irregular, basis. In particular gate alignment over the corner to corner areas deteriorated. See Fig (7). Several causes were tracked down. Firstly it was thought that mask to mask pattern integrity was perhaps being lost due to the mixing up of mask sets as a consequence of the change in mask thickness as described in Section 2.3 above. The masks are however "pulled" from the same master and, although the mask metal thickness does have a slight effect, tests on the alignment registration system proved this to be wrong. Another

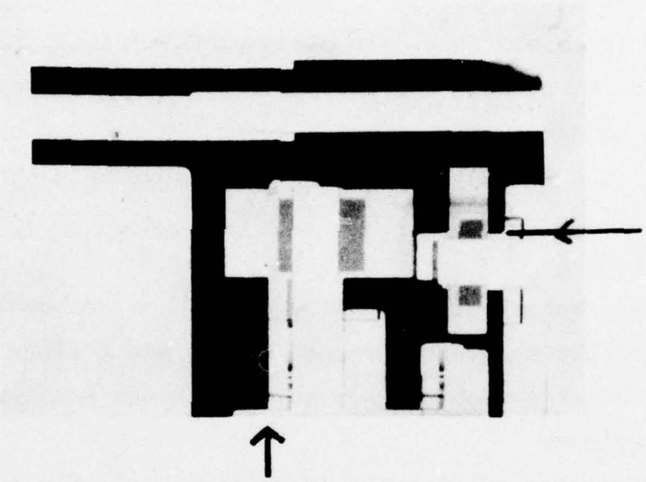

Fig (7) Gate alignment problem

possibility lay in the mask clamping.

It is difficult to reproduce the same tension on the mask holder clamps and in addition a degree of uncertainty was found to exist as to whether it was useful to tighten down both sides of the mask. When this was cleared up the problem still remained. Recently (Run 192, see Table (1) Section 7) the cause was pinned down pretty well definitively -- the teflon bushings on the master alignment jig were slightly worn! The bushings were replaced and to date four out of five circuits have been good in this respect, the one poor sample being an error.

Pattern sharpness (an early problem) looks to be solved although once in a while a small patch of fuzziness appears. This is known to be caused by mask ripples sometimes induced by magnetic "pulls". Fortunately, the thinner masks described above help this problem also.

2.6 Circuit Opens

Now that shorts are being cleared up the residual open bus lines are brought to greater focus. Opens are readily pinned down by electrical and microscopic observation although sometimes the cause is less than obvious.

One category of opens is "hair lines", Fig (8) illustrates this phenomena which occurs rarely but sufficiently often to cause problems. Fine opens ($\sim$0.2 μm in width) cut across circuit segments almost always in metal films although it is likely that they are most visible in metals and much less so in the transparent insulators. These lines characteristically cut busbars and are not found in adjacent pads but then can be seen in other adjacent segments.

This is characteristic of mask contamination once again. The segments broken correspond to the pattern segments on the same mask.

Lint is a possible contender but we are familiar with lint and related fibers and they are not so thin or smooth in appearance. Fine glass hair line defects are likely although the selective nature of the problem is hard to explain on that basis. An alternate glass substrate with much improved surface texture has been recommended by

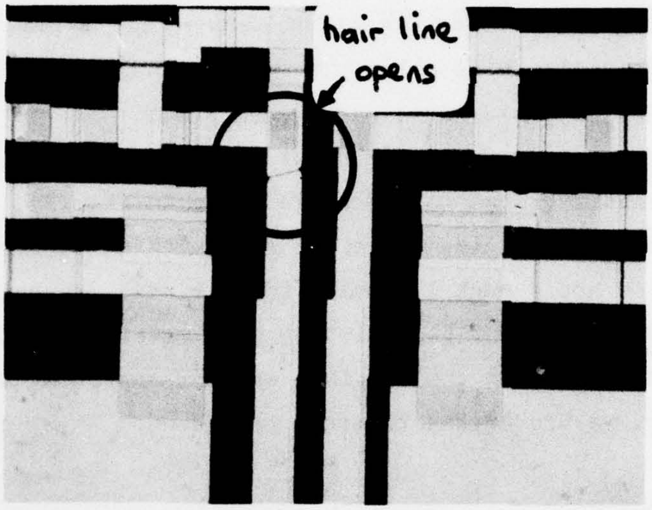

Fig (8) Hair line opens in busbars

Corning; this is low alkali as is the present glass. We have ordered this glass, however it is a long shot.

The most likely possibility, given the shape and appearance of this fine line, is a fine trace of DUCO$^{(R)}$ cement that has contaminated a mask. This is consistent with the evidence. DUCO is not used in the X-Y system and this problem is not found in the X-Y system. DUCO is almost impossible to see on the mask when it is this fine. DUCO burns out clean during anneal to give a clear line as is found. The DUCO is used as a back up adhesive to ensure the substrate does not fall off. Another technique, with double stick kapton tape is now being evaluated. This also will allow the insitu glass prebake that we are trying in order to avoid glass water adsorption.

A minor additional source of occasional opens (and sometimes shorts) is "rabbit tracks". These are shown in Fig (9), although this is an extreme example. The effect is a scratching of the films in small localized areas much like tiny foot prints. We believe that these are caused by abrasion of the films by mask metal asperities. The mask asperities are either in the original mask or appear as a result of mask clearing, we are trying to track this down.

2.7 TFT Properties

Consistency of the TFT properties (leakage current, threshold, etc.) is among the most encouraging aspects of the program so far. Table (2), Section (7), details the device property as to whether it is within the required specification shown in Table (2) of the third quarterly report, and repeated in Section 7.

The only question is the dc gate negative (off T_2) condition. If the device threshold is too negative it needs V_{GS} too negative for good long term stability. Various tests for this type of stability are being checked now; it has already been established that the doping of the TFT gap described last quarter improves this property.

Many circuits have been made that show very little drift under this condition. What we need is to ensure that this property is completely under control. A simple method of adjusting the external

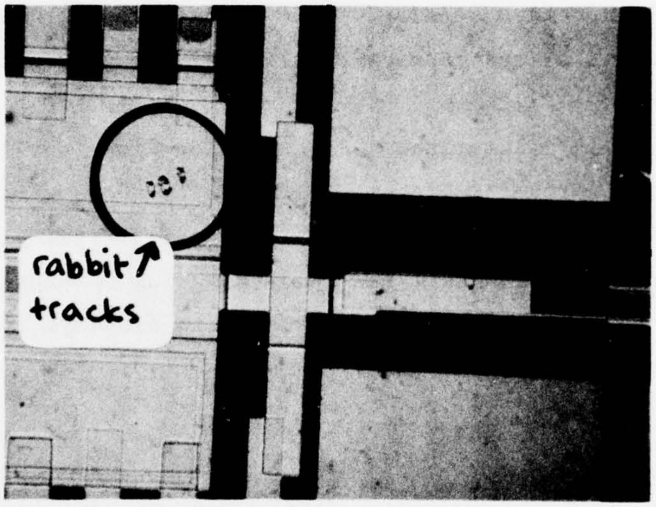

Fig (9) Rabbit tracks

address scheme so that the T_2 gates are not under a continuous V_{GS} negative condition has been developed; an outline schematic is shown in Fig (10). This address scheme is one answer; a better one is to ensure that the devices are made with the threshold close enough to $V_{GS=0}$ to avoid the need for large offset gate bias levels.

2.8 Conclusion

A wide litany of sources for circuit defects has been itemized. It is important to realize that we are comparing the TF circuits against an absolute perfection standard. The circuits being made are now very close in electrical and physical quality to the best made to date on the X-Y system.

Fig (11) illustrates the best pilot line fabricated display to date. Some further improvement in circuit opens will certainly bring the displays up to the quality of the X-Y displays. Following the guidelines detailed here and hence clearing up these minor but troublesome detail problems should result in displays of a defect level exceeding the best made to date.

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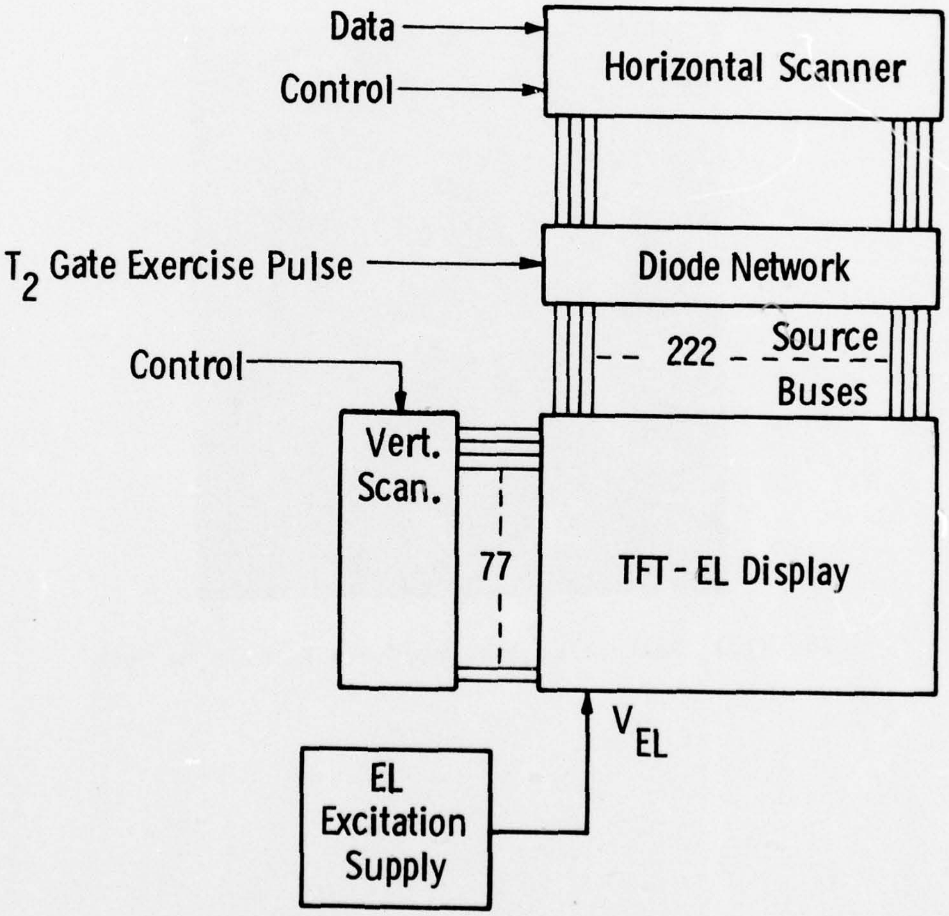

Fig. 10 — Alternate address scheme

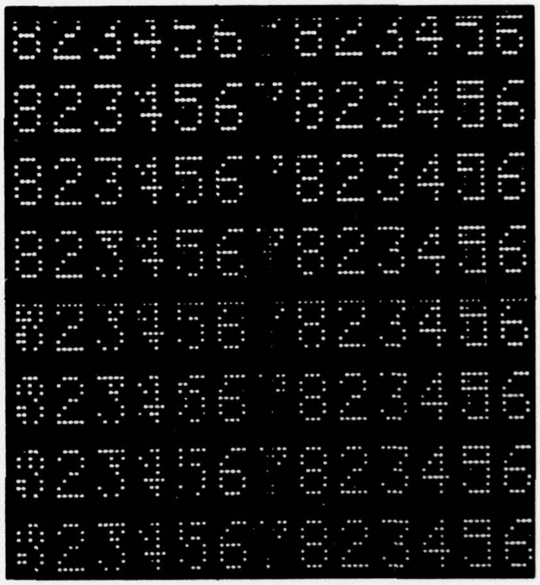

Fig (11) Best pilot line produced display to date

3. RESULTS AND DISCUSSION - SUBSEQUENT CIRCUIT PROCESSING

After fabrication and anneal the TF circuits that pass the acceptance tests are then coated with RISTON photoresist, exposed, developed and then phosphor sprayed. The final step is the evaporated top electrode, These steps are now discussed.

3.1 RISTON Process

No significant difficulties have been encountered recently at this step, It is now a fairly standard operation. The most frequent problem relates to the edge definition at the junction with the external power contacts. This edge must be "graded" to ensure no discontinuity; since modification of the photoplate this has not been a source of yield loss. One circuit was lost due to pressure of the "Colite" photoexposure vacuum pull down causing cracks in the substrate. This was traced to scotch tape left on the platen of the photoexposure unit. We now require that the platen be cleaned before and after each run.

3.2 Phosphor and Top Gold Electroding

Again this is not a prime area of concern although of course as yet large quantities of good, processable,circuits have not yet been put through this step. The major yield loss associated with this step has been some measure of irreproducibility in the gold conductivity and continuity. To improve the reproducibility a deposition shutter has been installed. However, the most troublesome problem (the patchy discontinuity) has been difficult to trace. We are now sure that it relates to the nature of the resistance "boat" used to evaporate the gold . An Al_2O_3 coated boat with a scoop shape is the best. It must have an appreciable affect on uniformity of the deposition although the substrate/source distance is ∿30". Thus in parts the Au is too thin and hence discontinuous. The Au is only ∿90°A so that a small variation can quickly reduce thickness to the point of discontinuity. Another possible cause is source heat causing solvent diffusion from the phosphor binder. Whatever the cause this problem has not been a source of major loss. Fortunately we check the continuity prior to top plate seal and the problem is easily detected. A repeat depositon usually solves the problem, however at the expense of added light adsorption in the extra gold which is ~65% transmissive .

3.3 Conclusions

Although this "packaging" area gets little detailed attention at the moment, the ability of the sequential processes to sustain yield when throughput is increased has not been properly tested. At the present program condition we are confident however that the process can handle increased throughput providing attention to detail is not lost.

4. FINAL TEST - LEGIBILITY, POWER AND CONTRAST

Further tests of legibility, power and contrast, were performed on displays fabricated to the required format etc. using the X-Y method. This display was of the "2-level" variety and had a dark contrast enhancing film behind each lit pad area. A brightness of 2000 fc was impinged on the display from a sun gun placed several feet away. The display brightness was adjusted so that the conditions of SCS 501 para. 4.5.2.1. were testable. The legibility test was performed with several observers, although, since this is not yet the formal test, the full rigor of para. 4.5.2.1. was not employed. All the characters were observable, (approx. 246 owing to edge losses). No errors were made at the 2000 fc ambient level. Two filters were used, a grey Polaroid^R, circularly polarized filter and a 3M^R green louver filter. Both were effective. The former less so but with no reduction in viewing angle. Under these test conditions i.e. with legibility at 2000 fc a power determination was made. With all characters on the dissipated power was only 980 milliwatts, well below the required (para. 4.5.3). 1.5 watts. The all "off" power was ∿100 mw (spec 1 watt) and the all "on" was 1.7 watts (spec. 2 watts).

A measurement of lit to unlit contrast was taken as per the conditions of para. 4.5.2.3. where the required specification is 20. The measured ratio of lit to unlit spot brightness was 21 [with filter; 50 fc on the display unlit; darkness, lit].

The actual spot brightness (no filter) was only ∿8 fl under the condition where legibility was achieved at 2000 fc. This low spot brightness, despite excellent high ambient legibility, results from the black underlayer. The legibility is however enhanced by this approach.

Final Test - Life

A 600 hrs life test has been set up and run under conditions identical to that required by SCS 501, except that for this initial run the display was maintained at room temperature. The entire panel is exercised (every element), the gates are scanned and the sources held at constant voltage. The EL voltage was set at a value to give 2000 fc legibility. The panel was set at 50 mins ON 10 mins OFF. Bias settings, defect counts, brightness and power dissipation were measured before and after the test. The results are shown in the attached Fig (12). Initial dissipated power - all elements on, 853 MW. Final dissipated power - all elements on 980 MW, within specifications.

Optimal bias settings	Initial	Final
S+	+12.5	+15.0
S-	-15.0	-20.0
G+	+10.0	+12.5
G-	-50.0	-50.0

No ON elements turned off and only ∿2 off elements turned on. A few (∿7) new shorts appeared.

Curve 691588-A

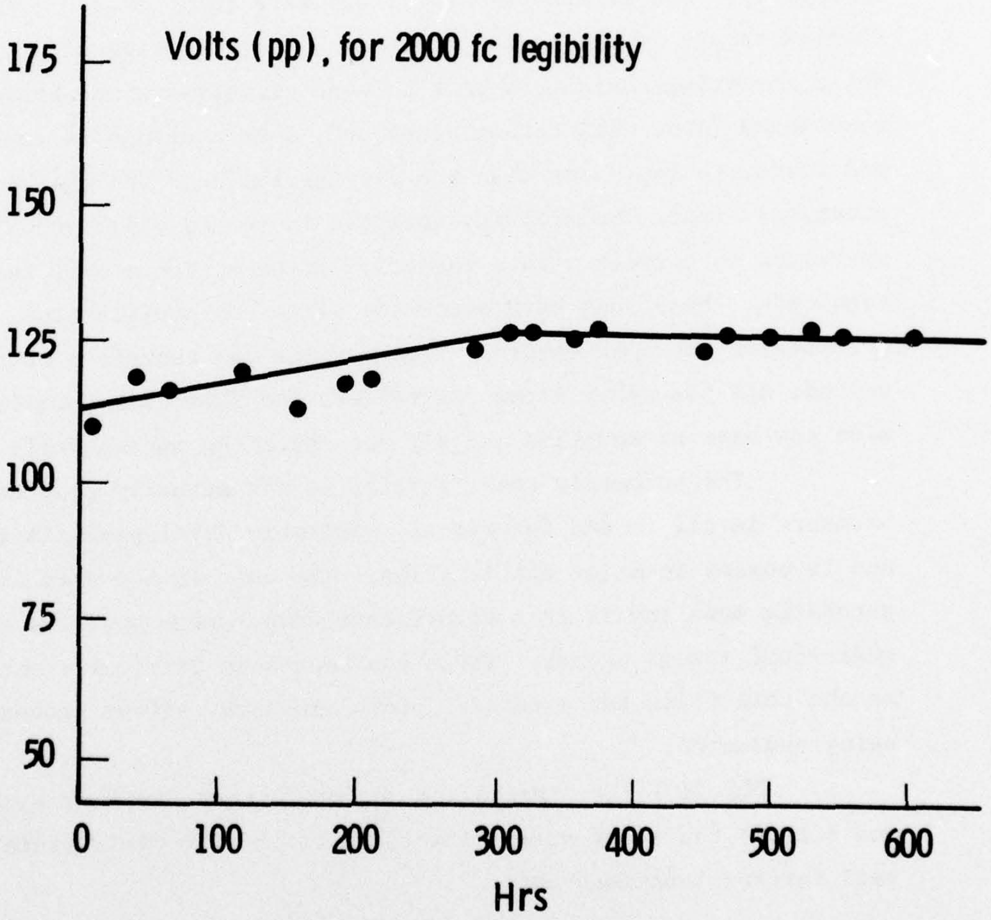

Fig. 12 — Constant brightness life test, 600 hrs at 2000 fc legibility level

5. EQUIPMENT MODIFICATIONS

Operation of the Sloan Deposition Controller was studied to determine the source of the power spikes. It was found that a binary-coded-decimal up-down counter integrated circuit was being used improperly. Two alternative solutions were identified, a fairly complex change in the logic circuitry or the addition of a capacitor. While inserting capacitors in TTL logic circuits is not normally considered "good engineering practice", such a change is much easier and faster to implement than the alternative, and was therefore attempted first. Sensitivity analysis indicates experimentally that operation is correct with a variation of capacitance over two orders of magnitude. Many runs have been made since the modification, with no evidence of improper control. The problem can therefore be considered solved; all the other Sloan controllers the Thin Film Department have also now been so modified and all are operating successfully to date.

The automatic test facility is now actually complete and the hardware is all in and functional. Software development is in hand and is posing no major difficulties. The unit is now used in a semi-automatic mode and it is a significant advancement over the old individual manual probes. There has been some difficulty with scratches on the thin films due excessive probe pressure, softer probes are being evaluated.

Fig (13) illustrates the automatic test facility probe station and Fig(14) the relay matrix interface to the H-P minicomputer and test forcing functions unit.

Fig (13) The automatic circuit test facility- probe station

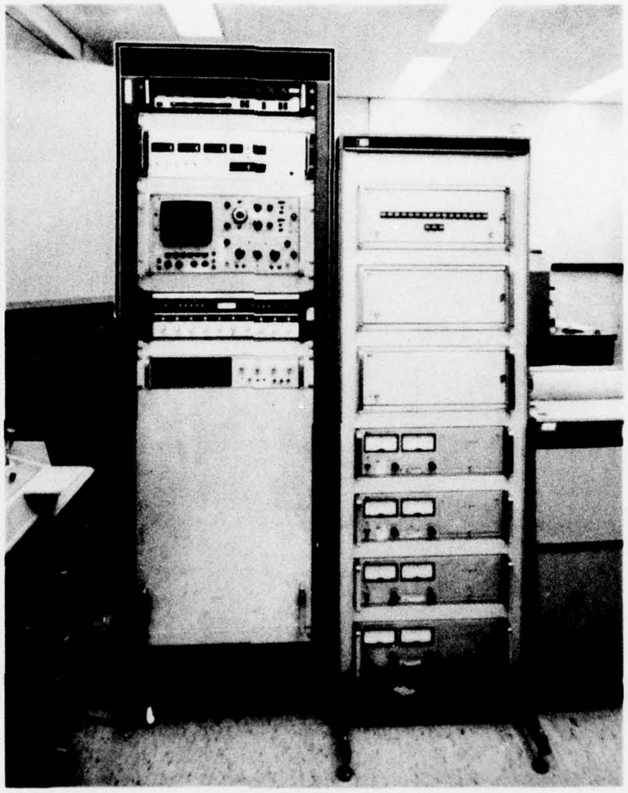

Fig (14) The automatic circuit test facility
CPU interface etc.

6. RESULTS OF X-Y FABRICATION OF DISPLAYS

Paralleling the fabrication of the DMD display on the pilot line, through the use of dedicated masks, is an effort to produce the same device on the laboratory style X-Y unit. This it should be noted is a Westinghouse funded operation but the displays being fabricated are to the required specifications of SCS 501.

Since the assignment of Dr. F. C. Luo to the pilot line, Dr. H. Y. Wey has taken over this X-Y fabrication. This has of necessity involved some new relearning delay but some improvements have also been made. In particular more rigorous chemical removal of bead blast* residues in the vacuum chamber and interior fixturing has resulted in faster pump-down and better chamber vacuum. Also better methods of holding the substrate have been tried to improve the "yield" on the X-Y process.

Fig (15) illustrates the latest display made on the laboratory unit.

In addition we have investigated, as an alternate production concept, the possibility of automating the X-Y process. Complete automation of the movements appears from this analysis to very expensive. There are a number of possible methods of picking up precise locations in X and Y planes using commercial machine tool locators, however transferring that information to precise stepping motors would be very difficult. An alternate concept is to use automatic check procedures coupled with manual location setting. This idea is being further investigated as a way of making a potential manufacturing unit out of the lab equipment for the long term.

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*bead blasting is used to clean residues of depositon after each run.

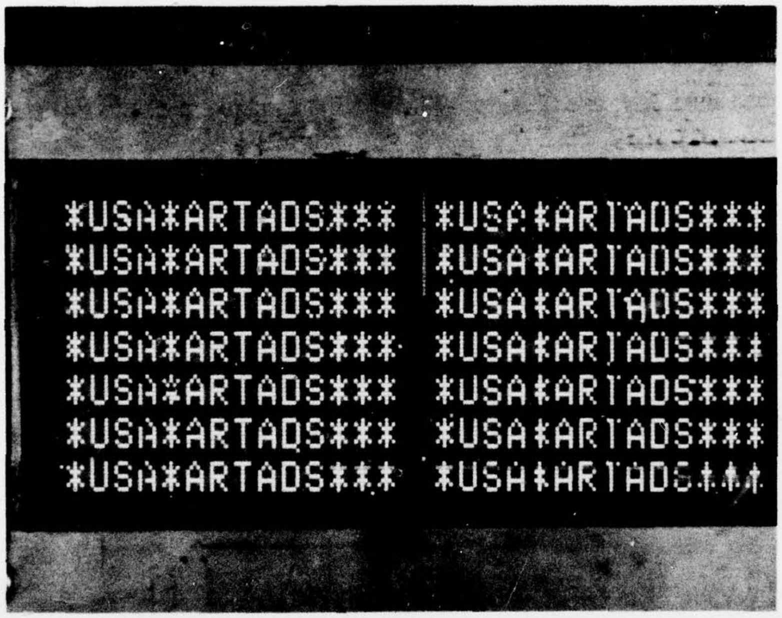

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Fig (15) Best display produced recently on the X-Y facility

7. OVERALL CONCLUSIONS AND SUMMARY TABLE

The attached table summarizes the circuits fabricated in recent months. The data are obtained by comparative measure using established standards. A recent display is shown in Fig (11). There has been a marked improvement this quarter.

The above data is plotted in Fig (16)-Fig (18). The overall conclusion is clear; significant improvements have been made and the overall quality in electrical and physical film properties is now very close to the best obtained in previous work on laboratory facilities. A measure of improvement in open circuits ought to result in at least comparable quality to our previous best X-Y produced display. Most important we also have a clear understanding of the cause and effect factors regarding the other residual defect sources that augurs well for even further improved quality.

Table (1)
Data Summary

SUBSTRATE	ANY CONTROL PROBLEM	DOUBLE KOVAR BACK-UP	ALIGNMENT RATING	SHARPNESS RATING	INSULATOR QUALITY RATING	RIPPLED ALUMINUM	DOPED GAP: Method & Thickness	NUMBER OF SHORTS	COMMENTS
147-3095-4 +(3914)		NO	60 MIN=50	25	25	NO	0	>10	
151-3096-6 +3914		NO	70 MIN=50	37	35		3 TIMED	>10	
152-3097-8 +3914		NO	35	45	20		3 TIMED	>10	
157-3102-4		YES FRESHLY* S.B.	50 MIN=0%	50	60		3 TIMED	>10	Insul. shifted
158-3103-6		YES FRESHLY S.B.	70 MIN=25%	75	30		3	0(G-GR) 3(S-G) 13(S-GR)	
160-3104-6		YES FRESHLY S.B	0** (75)	75	60	YES	3 AUTO	--	No gates No cracked ins
161-3106-8	YES	YES FRESHLY S.B	0** (75)	75	35	YES	2 AUTO	--	Step 12 Al_2O_3 No gates Cracked ins.
New shutter in for this run 165-3104-6		YES; Thin Masks	55 MIN=25	90	80	YES	3 AUTO	>10	Handling scratch Press = $6x10^{-7}$ torr Poco crucible scrubbed mask cracked ins.
166-3107-8		YES, Thin Masks	50 MIN=0	90	55	YES	3 TIMED	>10	Used poco crucible scrubbed masks No cracked ins.

Å

*Sand Blasted

**Neglecting loose mask

Table (1) - continued

SUBSTRATES	ANY CONTROL PROBLEMS	INTERRUPTED SEQUENCE	DOUBLE KOVAR BACK-UP	ALIGNMENT RATING	SHARPNESS RATING	INSULATOR QUALITY RATING	RIPPLED ALUMINUM	DOPED GAP: Method & Thickness	NUMBER OF SHORTS	COMMENTS
173-3107-6	NO	YES	YES	62 (21.7)	59 (37.5) MIN=0	88 (12.5)	YES	3A TIMED	∿7	Occas. cracked insul Screened Al_2O_3 "Rabbit" tracks
174-3110-8	NO	NO	YES	63 (35)	55 (32) MIN=0	95 (11.2)	YES	3A TIMED	∿8	Army visit today Unscreened Al_2O_3 "Rabbit" tracks
178-3112-6	NO	NO	YES	95 11.2	82 (17.5)	95 11.2	YES	3A TIMED	0(G-GR) 2(S-G) 0(S-GR)	Slight leak in actuator
179-3113-8	YES	NO	YES	56 (13.4)	73 (18.2)	95 (11.2)	YES	3A TIMED	1(G-GR) 0(S-G) 0(S-GR)	Slight leak in actuator
Raised CdSe Rate to 4 181-3114-4	NO	NO	YES	25 (0)	66 (25)	95	YES	3A TIMED	NA	Some Al spots (Rated before anneal)
CdSe= 4A/SEC 186-3115-6	NO	NO	YES	82 (20.1)	70 (22.0)	95	YES	≈8A	>10	Open bus bars Freq cracked ins
(All thin except mask 15) 189-3116-6 S-D Contact= 1000A	NO	NO	YES	74 (29)	60 (10.6)	95	YES	3A TIMED	∿2	Occasional cracked insul, "Rabbit tracks"
192-3117-2 S-D Contact= 1000A	YES; Step 5 Rate	NO	YES	84 (21.9)	82 (17.5)	95	YES	3A TIMED	∿4	"Rabbit tracks"
196-3116-6	NO	YES 45 Min @ Step 6	YES	86 (17.8)	88 (16.4)	93 (4.5)	YES	3a TIMED	∿3	Cracked insul "Rabbit tracks"
199-3117-8	YES; Crystal Step 14	NO	YES	70 (13.2)	84 (17.1)	91 (5.4)	YES	3A TIMED	∿3	Dirty glass one area cracked ins "rabbit tracks"
201-3116S-6	NO	NO	YES	86 (6.5)	95	95	YES	3A TIMED	∿1	Mask abrasions Some cracked ins Al splotches,
202-3117-8	YES; Computer problems	NO	YES	93	90	83	YES	3A TIMED	∿2	Mask abrasions

TABLE (2)

TFT Properties

Since almost all the devices come within spec the only meaningful data listing is the <u>exceptions</u>.

A listing of shorts is given in Table (1).

Device Properties - Typical

T_2 logic TFT	I_{dsatt} $V_{GS} = +20V$	250μa
	I_{off} $V_{GS} = -20V$ $V_{SD} = +25V$	1-3na
T_1 power TFT	I_{dsatt} $V_{GS} = +20V$	300μa
	I_{off} $V_{GS} = -20V$ $V_{SD} = +200V$	~0.5μa
	V_B $(V_{GS} = +6V)$	$>250V_{SD}$

Exceptions:

Leakage current high (>3 na, $V_{GS} = - 20V$)

179-3113
181-3114
189-3116
152-3097
157-3102

due mostly to misaligned gates

poor breakdown strength (<250V) due to excessive specs

186-3116
147-3096
152-3097
161-3106

Also several circuits are now lower in on current [(I_{dsatt}) current] than listed in the table. This may be a consequence of the gap doping. However since I_{dsatt} was always higher than necessary it is of no consequence. A more typical value now is

I_{dsatt} = 150 µa logic TFT
I_{dsatt} = 250 µa power TFT

Curve 691590-A

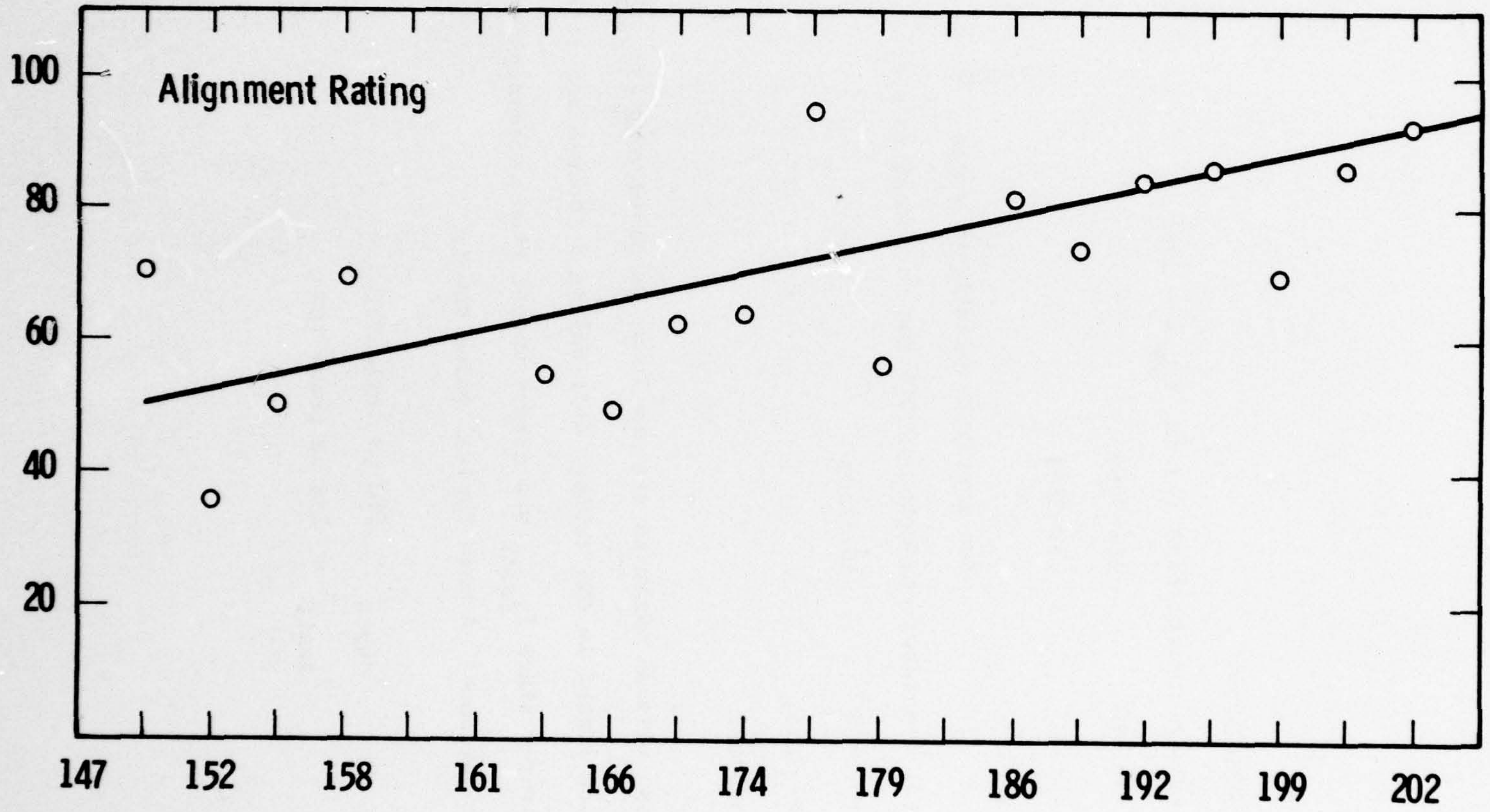

Fig. 16 — Recent results alignment rating

Curve 691591-A

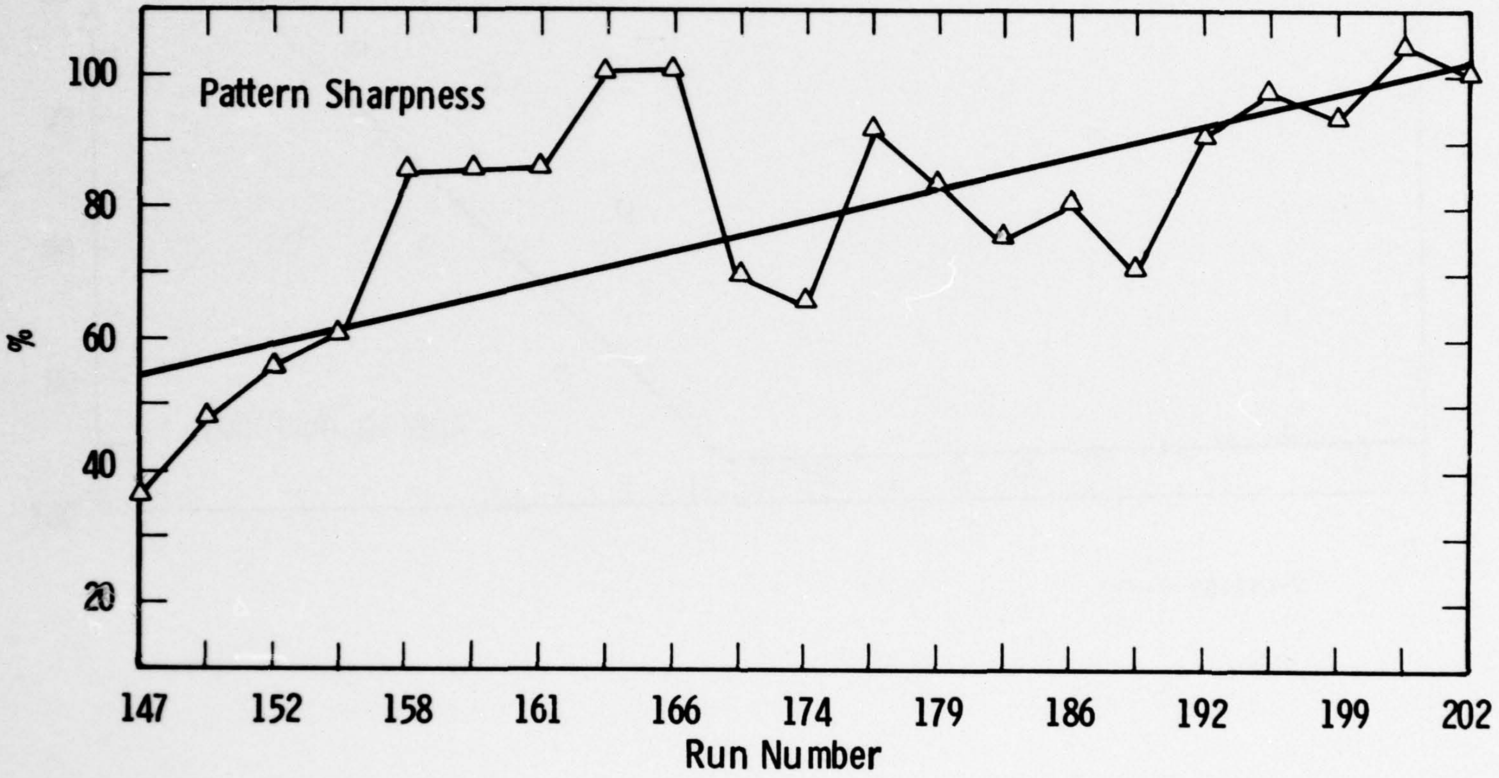

Fig. 17 — Recent results sharpness rating

Curve 691589-A

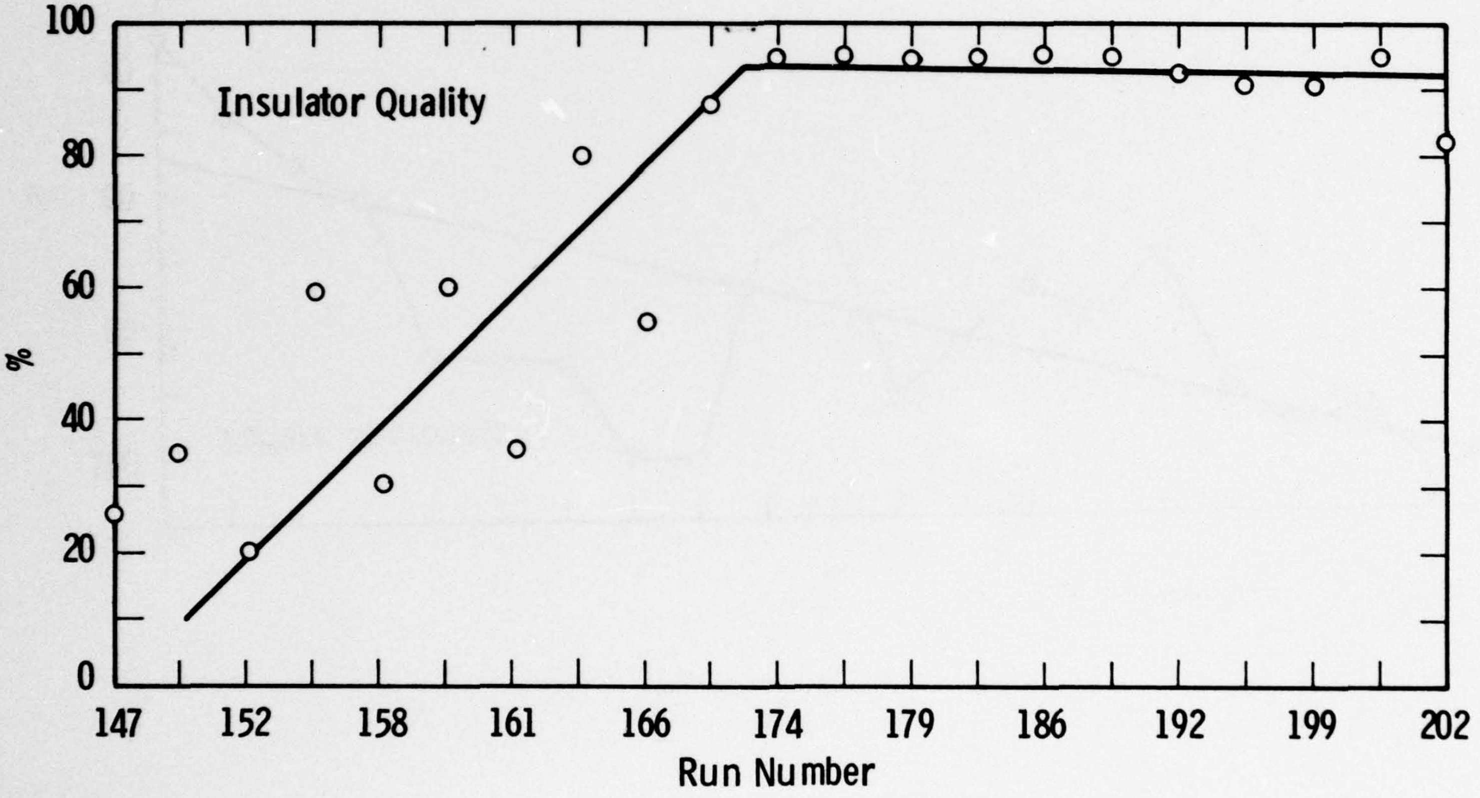

Fig. 18 — Recent results insulator quality

8. EXPECTED RESULTS NEXT QUARTER

1. Displays of quality comparable to those fabricated on the X-Y system will be made and shipped to the Army as engineering samples.
2. Further improved displays will be fabricated and tested regarding the requirements of SCS-501.

9. PUBLICATIONS AND REPORTS

None

10. IDENTIFICATION OF PERSONNEL

A listing of people and hours charged to this contract in this quarter would only constitute a small amount of the total program since, as is well-known to the Army a major company funded program parallels this effort. All the Research Thin Film Devices personnel are now carried on the Westinghouse program. They include:

Engineers	Technicians
Dr. David H. Davies	F. S. Youngk
Dr. F. C. Luo	H. B. Shaffer
Mr. R. E. Stapleton	D. Leksell
Mr. S. D. Burkholder	

All the above are substantially 100% on the program.

Directly charged to the program in this quarter are:

		hours charged
Engineering:	T. Csakvary	448
	W. L. Rogers	
Technicians:	I. Gessner	586
	W. Brendlinger	
Management:	Dr. M. Green	~80

Additional minor efforts were put by various personnel.

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